

# SEVEN YEARS OF PHENOMENAL ACHIEVEMENTS



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*In just last 10 days, the country faced 2 big cyclones. Cyclone Tauktae on the western coast and Cyclone Yaas on the eastern coast... In last few years we have been able to significantly reduce loss of lives due to natural disasters like the recent cyclones.*

**- Hon'ble PM Sh Narendra Modi**  
*on his Mann Ki Baat, aired on 30 May 2021*



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*India has one of the best weather forecasting systems in the world, providing accurate advisories to multiple stakeholders. Investments in National Monsoon Mission & High Performance Computing facilities of MoES have provided estimated benefits of Rs 50,000 cr to our farmers, fisherfolk & livestock rearers.*



**Dr Harsh Vardhan**

*Hon'ble Minister of Earth Sciences  
Government of India*

## 1. INTRODUCTION

The mandate of the Ministry of Earth Sciences (MoES) is to provide services for weather, climate, ocean and coastal state, hydrology, seismology, and natural hazards; to explore marine living and non-living resources in a sustainable way and to explore the three polar-regions (Arctic, Antarctic and Himalayas). Some of the most important achievements which include a wide variety of services that are relevant to the society over the past four years (2014-2021) are given below.



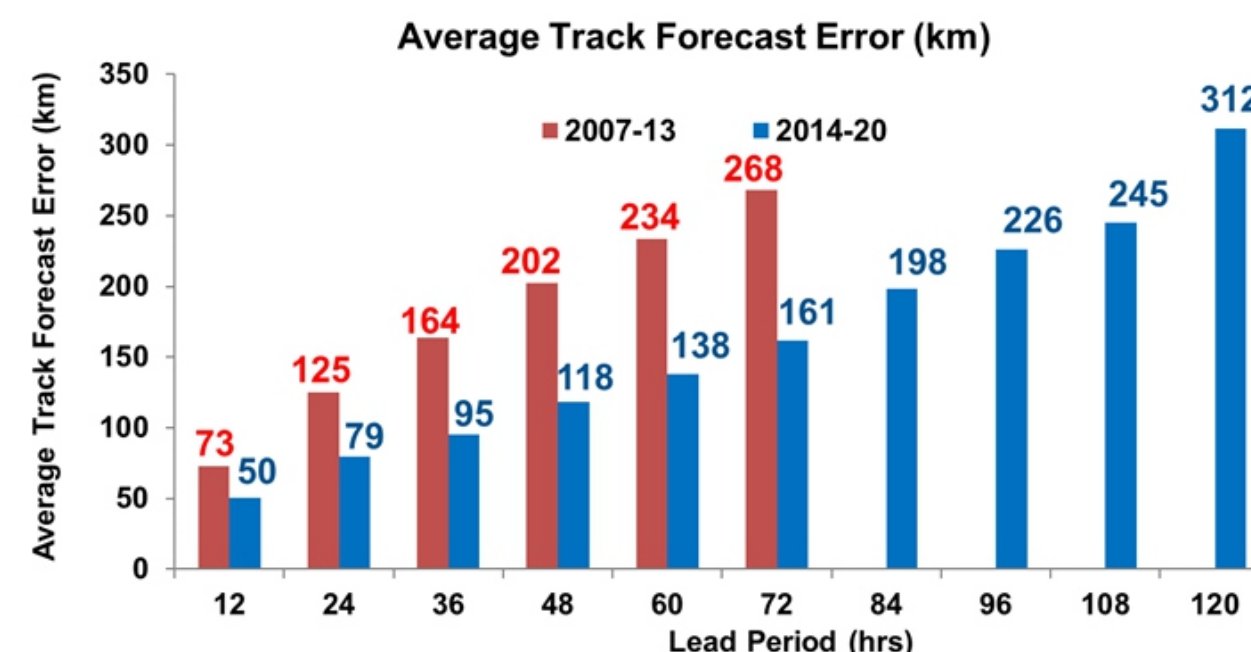
## 2. NATURAL DISASTERS- EARLY WARNING SYSTEMS

The Indian region is frequently affected by a variety of hydro-meteorological disasters such as heavy rains, tropical cyclones, Tsunamis, storm surges, severe local storms like thunderstorms, hailstorms, cloudburst, tornadoes, floods, heat and cold waves, etc. There are 13 coastal states/UTs encompassing 84 coastal districts which are affected by tropical cyclones. The states falling within the periphery of "India Flood Prone Areas" are West Bengal, Orissa, Andhra Pradesh, Kerala, Assam, Bihar, Gujarat, Uttar Pradesh, Haryana and Punjab. Heat waves are more frequent over the Indo-Gangetic plains of India. Northern and eastern states are affected by cold waves. Thunderstorms are more frequent and intense over east and northeastern India and severe fog occurs over the Indo-Gangetic plains in the winter season.

### 2.1 Cyclone warning services

The India Meteorological Department (IMD) issued accurate and timely prediction of tropical cyclones, combined with fieldwork by disaster management agencies, that helped save thousands of precious lives of countrymen. There has been continuous improvement in forecast accuracy with decrease in track and landfall forecast errors and increase in skill over the last 7 years.

### Comparison of Average track forecast errors of cyclonic storms over the Arabian Sea & Bay of Bengal during (2007-2013) & (2014-2020)



The above figure shows the comparison of the average track forecast errors spanning the 7 year period viz., 2007-2013 Vs. 2014-2020. A steady improvement in the track forecast errors and also the increase in lead period of track prediction upto 5 days are evident in the latest 7 year period. The average track forecast error has reduced from 125 km to 79 km and from 268 km to 161 km in 24-hours and 72-hour forecasts respectively. More importantly, there has been a significant reduction in loss of human life and reduction in the cost towards evacuation and payment of ex-gratia to affected people.

### 2.2 Tsunami Early Warning

The Indian Tsunami Early Warning Centre (ITEWC) monitored 143 earthquakes of magnitude  $\geq 6.5$  during the period 2014 to March 2019. Out of these, 12 moderate earthquakes occurred in the Indian Ocean region. For these earthquakes, ITEWC disseminated the bulletins as per standard operating procedure to its regional (Indian Ocean Countries) and national (India) stake holders. The new Decision



Support System (DSS) version 2016 was tested extensively during IOWave16 tsunami mock exercise and made operational in December 2016. The new DSS is integrated with the necessary metadata layers, latest version of Area of Service (AoS), Earthquake Source Zone (ESZ), CFPs and CFZs. As part of the Tsunami Warning System, INCOIS/MoES has completed mapping the highly vulnerable coastal regions to natural disasters such as tsunami and storm surges using 3D GIS technique for several locations in the east coast of India.

### **Tsunami ready communities**

IOC-UNESCO conferred the Certificate of Recognition and Certificate of Appreciation as Tsunami Ready communities to Venkatraipur and Noliasahi village communities and OSDMA Officials, through a virtual event organized on 7 August 2020, which is first of its kind in the Indian Ocean region.

### **2.3 Heatwave warnings**

IMD collaborated with the National Disaster Management Authority to devise the National guidelines for the management of heat waves and with the states for formulating Heat Action Plans to reduce heat-related mortality and morbidity in the country.

### **2.4 Commissioned Integrated Flood Warning Systems (IFWS)**

MoES commissioned IFWS for Chennai in November 2019 and for Mumbai in June 2020. The systems have been handed over to the respective State Governments. They prove extremely useful in mitigating damage caused due to impending urban floods.

### **2.5 Flash Flood Guidance System**

IMD Launched the Flash Flood Guidance Services, the first of its kind for South Asian countries namely India, Bangladesh, Bhutan, Nepal and Sri Lanka

### **2.6 Real Time Monitoring of Seismic Activity**

National Center for Seismology (NCS) is the nodal agency of Government of India, primarily responsible for monitoring seismic activity in and around the country. The operational task of the Center is to quickly estimate the earthquake source parameters immediately on occurrence of an earthquake and disseminate the information to all the user agencies including the concerned State and Central Government agencies responsible for carrying out relief and rehabilitation measures.

#### **Upgradation of the seismological network in India**

The MoES upgraded the country's seismological network to 115 stations and implemented a state-of-the-art auto-location software called SeisComp3 with operational capability to detect M:3.0 and above for most part of the country. This network would provide a more accurate estimate of preliminary earthquake parameters, which will enhance the scientific understanding of earthquakes. with operational capability to detect M:3.0 and above for most part of the country.

#### **Conducting seismic microzonation**

Seismic microzonation helps categorize earthquake-prone areas into risk zones that provides the basis for site-specific risk analysis, which can assist in the mitigation of earthquake-related damage. MoES has executed seismic microzonation of Bhubaneswar, Chennai, Coimbatore and Mangalore, which are in an advanced completion stage. In eight more cities (Patna, Meerut, Amritsar, Agra, Varanasi, Lucknow, Kanpur and Dhanbad), work has been initiated.

#### **Establishing National Geochronology Facility**

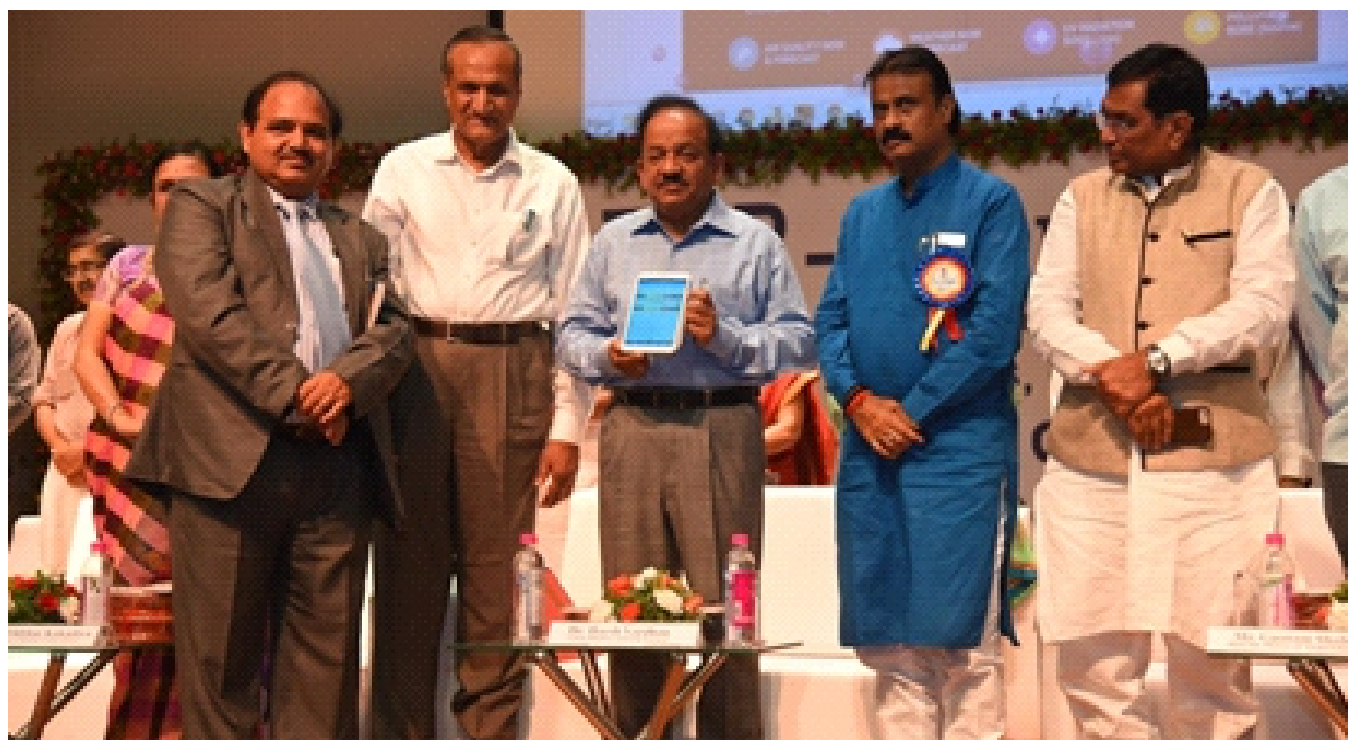
The MoES worked towards setting up the National Geochronology Facility at Inter-University Accelerator Centre in New Delhi. It will

enable Indian scientists to generate high precision quality geochemical and isotopic data. It will allow researchers to estimate the geological age of Earth's formations, rocks, sediments, etc. and improve understanding of the evolution of the Indian lithosphere.

## 2.6 Air Quality–Early Warning System

In view of growing societal importance in air pollution problem, MoES has introduced a major national initiative, “System of Air Quality and Weather Forecasting and Research” known as “SAFAR” for greater metropolitan cities (Delhi, Mumbai, Pune and Ahmedabad) of India to provide location specific information on air quality in near real time and its forecast upto 1–3 days in advance.

**SAFAR–Ahmedabad an integrated early warning System of Air Quality, Weather and Health was dedicated to the Nation by Dr. Harsh Vardhan, Hon'ble Union Minister for Science & Technology and Earth Sciences along with several State Ministers and dignitaries on 12 May 2017 in Ahmedabad.**



The current observations and forecasts are disseminated through various user-friendly communication media such as SAFAR–Air (Mobile app for Android and I-phone).

**MoES developed and commissioned a very high-resolution (400 meter) AQ–EWS for Delhi. It can predict extreme air pollution events in Delhi and give warnings to take necessary step as per Graded Response Action Plan.**

## 2.7 Commissioning of new Doppler Weather Radars (DWRs)

The MoES commissioned four new DWRs at Srinagar, Sonamarg, Kufri, and Mukteshwar. The radars will provide information on severe weather events and support disaster management authorities. It will also help the authorities mitigate risk to pilgrims of Kailash Manasarovar and Char Dham yatra.

## 2.8 Meteorological Centre (MC), Leh

Meteorological Observatory (MO) Leh was upgraded into full-fledged Meteorological Centre (MC) after Ladakh became a union territory on 31 October 2019. The Meteorological Centre at Leh was inaugurated on 29th December 2020 by Hon'ble Minister for Earth Sciences, Dr Harsh Vardhan.

### 3. SERVICES TO THE FARMERS AND FISHERMEN

#### 3.1 Agro-Meteorological Advisories Services (AAS)

Weather and Climate variability plays an important role on agricultural activities, like sowing, harvesting, applying irrigation and pesticides etc. The Ministry of Earth Sciences (MoES) in collaboration with the Indian Council of Agricultural Research (ICAR) provides the Agromet Advisory Services (AAS) for the benefit of farmers. Farmers make use of these services for planning the operations like sowing, irrigation, application of fertilizer and pesticide, harvest and protection of crops from weather disasters. The services carried out at 130 agro-met zones (cluster of 4-6 districts) now have been successfully extended to the district level and operated across 608 districts of the country. Currently, about 42.0 million farmers are receiving crop specific agro-meteorological advisories in vernacular languages. MoES is working towards the goal of setting up District Agro-Met Units (DAMUs) in all districts of the country. Presently 310 DAMUs have been established issuing AAS to 690 districts and 2256 blocks.

#### 3.2 Potential Fishing Zones (PFZ) and Tuna PFZ Advisories

PFZ advisory has evolved as a flagship programme of Indian National Centre for Ocean Information and Services (INCOIS) which directly benefit tens of thousands of fishermen and their family. The advisories are disseminated in smart map and text form on a daily basis, depending on satellite data availability except fishing-ban period and during adverse sea-state. INCOIS provides PFZ advisories to about 7 lakh fishermen on a daily basis to help them to easily locate the areas of abundant fish in the ocean. In 2014, this number was just 1 lakh fishermen. These services also help fishermen to earn more

income due to more catch and reduce unnecessary expenses in using fuels.

#### 3.3 Estimating economic benefits of MoES services to the country

India's investment of nearly 1,000 crores through the Monsoon Mission and High-Performance Computing yielded benefits worth rupees 50 thousand crores to ~10.7 million below poverty line (BPL) agricultural households and 0.53 million BPL fisherfolk households over a period of five years. About 26.6 per cent of this benefit is attributed to womenfolk. The findings were published in a recent report released in November 2020 by the National Council of Applied Economic Research (NCAER), an independent, non-profit economic policy research institute in New Delhi.



## 4 OCEAN SERVICES

**4.1 Ocean State Forecasts** ( forecasts of waves, currents, sea surface temperature, etc.) to fisher folk, disaster management authorities, shipping industry, oil and natural gas industry, Navy, Coast Guard and other stakeholders have improved considerably during the last 4 years. INCOIS also provides the OSF services to several Indian Ocean rim countries including Sri Lanka and Seychelles under the umbrella of Regional Integrated Multi-Hazard Early Warning System (RIMES) for the Afro-Asian Region. At present, the ocean state forecasts are provided to approximately 16.7 lakh users on daily basis.

### 4.2 Oil-spill Advisory

INCOIS/MoES has been providing oil spill advisories whenever such incidents of oil spill occur over the Indian Ocean. INCOIS/MoES issued the bulletins predicting the trajectory of the oil spill occurred, off Ennore port due to the collision of two ships on 28 January 2017 at 13.228° N, 80.363° E which spilled around 20 tons of HFO oil. The Indian Coast Guard used these predictions to plan and execute the clean-up operations.

### 4.3 Search and Rescue Aid Tool

INCOIS/MoES developed a Search and Rescue Aid Tool (SARAT) to track any objects/persons lost at sea. Predicted ocean currents and surface winds at the last known location, are used to estimate the probabilities of finding the missing object/person in the sea. Dr. Harsh Vardhan, Hon'ble Minister of Science & Technology and Earth Sciences dedicated SARAT to the Nation on 27 July 2016. INCOIS/MoES also developed a mobile App for handy use of SARAT. This App can assist with searching of over 64 types of missing 'objects' in the ocean including boats, ships, man-on-board etc. App is available for download from Google Play Store under the name "SARAT".

### 4.4 Digital Ocean

The Indian National Centre for Ocean Information Services (INCOIS), Hyderabad, launched the Digital Ocean, a one-of-its-kind web-based platform for ocean data management in India. The portal will make ocean-related data available to a wide range of users, including research institutions, operational agencies, strategic users, academia, maritime industry and policymakers.

### 4.5 Monitoring coral reef health at Gulf of Mannar

The National Center for Coastal Research (NCCR), Chennai has been monitoring coral reef health at Gulf of Mannar since 2018. The scientific endeavour assesses the total live and dead coral coverage, community structure of reef-building corals, anthropogenic influences and threats faced by the coral ecosystem. NCCR has published two extensive technical reports entitled a) Coral Reef Health Monitoring and b) Coral Health Index. The reports provide valuable information about the present health status of coral reefs of Gulf of Mannar, statistical update on their health status, threats faced by the reef ecosystems, and recommendations for their long-term conservation. The reports would hugely benefit academicians, policymakers, and researchers in making effective conservation and management plans for Gulf of Mannar and Palk Bay.

### 4.6 Measuring shoreline change rate for the Indian coast

The National Center for Coastal Research (NCCR), Chennai has analysed shoreline change rate for the Indian coast using Indian satellite images and field measurements. A comprehensive web-based coastal change information system has been developed to facilitate coastal managers in the development and management of coast-related processes. In addition, seasonal monitoring of beach morphology and coastal changes, observations of sediments and littoral environment have been conducted at 14 sites to understand sediment dynamics, which would aid estimating shoreline change due to climate change.

#### 4.7 Marine Living Resources:

Marine resources available in the Indian Ocean are scientifically documented which envisages exploration of marine hotspots, inventorying and documenting its biodiversity from intertidal region through all along the Indian EEZ. Also the areas beyond national jurisdiction (ABNJs) are taken up as regional initiatives to address the marine biodiversity of oceanic and coastal waters.

A comprehensive database containing about 1, 20,000 records of more than 6500 marine species have been created with complete details of location, depth, taxonomic classification and hydrographic data. The entire dataset is available at Ocean Biogeographic Information System (OBIS) hosted by IODE/IOC program. A digital catalogue on new marine species including species which are described as new to science from the Indian Ocean region has been created.

Andaman and Nicobar shelf system has been identified as one of the 'hot spot' for benthic fauna. Area off Diglipur, 13°15'N, 93°15'E in the Andaman Sea, at a depth of 670m was found to be a heavy sponge bed with rich and highly diverse deep sea fauna.

#### 4.8 Mapping the coastal water quality index (CWQI)

A coastal water quality index (CWQI) map was prepared for the Andhra Pradesh coast based on the results obtained from the cruise conducted in August 2020. Shoreline change rate for the entire Indian coast is analysed using Indian satellite images and field measurements. 526 numbers of shoreline change maps (1:25000 Scale) have been generated using standard protocol using 11 data sets for 1990–2018.

## 5 OCEAN TECHNOLOGY

### 5.1 Setting up of desalination plants to provide potable water to island communities

Considering the importance of fresh water for islands, Low Temperature Thermal Desalination (LTTD) plants of 100 m<sup>3</sup>/day capacities are being established in the Union Territory of Lakshadweep. MoES set up a desalination plant at Kalpeni in Lakshadweep Islands that started generating potable water in January 2020. Five more desalination plants are being set up in the Lakshadweep islands of Amini, Androth, Chetlat, Kadamat, and Kiltan. The desalination plants would provide clean potable water to island communities by utilizing seawater and will enhance the quality of life of local dwellers significantly.

### 5.2 Shore Line Protection

Coastline-specific solutions based on the sedimentation process and littoral drift were undertaken in various Indian ports for effective erosion control. Seawalls and groins are constructed by the Puducherry government at various timelines to mitigate the coastal erosion problem, but erosion shifted further North. To evolve long term shore protection measures for beach restoration, a detailed study was undertaken for long term shore protection which includes long term shoreline change analysis, detailed processed based measurement and numerical modelling. A hybrid solution with two submerged reefs and beach nourishment were identified to restore the lost beach along Puducherry.. Currently, the beach has already formed south of wedge reef to an extent of 600m and with the steady progress of the project the city's coastline can soon travel back in time to its sandy past.



BEFORE IMPLEMENTATION



AFTER IMPLEMENTATION

### 5.3 Open Cage Culture

Large scale fish production through mariculture is the viable alternative to cope with the ever increasing demand for fish proteins. An open sea cage culture mooring system was designed and developed for commercially important marine finfishes suitable for Indian sea conditions to meet this demand with available marine engineering and biological expertise. A cage with multipoint mooring were deployed and tested in the North Bay (Andaman Island), Olaikuda (Tamil Nadu) and Kothachathram (Andhra Pradesh) representing fully protected, semi-protected and open sea environments, respectively). Besides this, an innovative concept of rearing post larval fishes in a specially designed nursery cage in open sea was developed and geospatial analysis of Indian Seas was conducted to estimate the fish farming potential of the country. The open sea cage culture technology seems to be an ideal alternative livelihood option for the coastal fishers, help generate considerable employment opportunities in the country; to meet the fish food production targets of the nation.

### 5.4 Commissioning of two coastal research vessels

Two new coastal research vessels—Sagar Tara and Sagar Anveshika—joined the MoES fleet of research vessels after successful and satisfactory harbour and sea trials. The project was conducted in partnership with India's private sector, boosting the vision of 'Make in India'.

### 5.5 Deep-sea underwater Mining Machine

Ocean is a rich source of living and non-living resources. Minerals such as gas hydrates, polymetallic nodules, polymetallic sulphides are abundant in Indian EEZ and Indian Ocean. Polymetallic nodules, which are rich in Cobalt, Nickel, Copper and Nickel, are available at about 5500 m water depth in the Central Indian Ocean Basin. An area of 75,000 sq.km has been allotted to India by the United Nations after India conducted an extensive survey of 150,000 sq. km of Central Indian Ocean. MoES is involved in exploration and harvesting of these resources. A crawler based mining machine with a flexible riser is being developed for the mining of the nodules from 5500 m water depth. As a first step towards harvesting the nodules, a seabed crawler based mining machine was developed and demonstrated at a 500m water depth. Based on the experience a mining machine is now being developed for 6000 m water depth. To test the strength of the soil at those depths an in-situ soil tester also has been developed and deployed up to a maximum depth of 5462 m at the polymetallic nodule site in the Central Indian Ocean. A deep water work class Remotely Operated Vehicle (ROV) was developed to aid the exploration of the deep ocean minerals at 5500 metre depth. Locomotion trials of Underwater Mining Machine was successfully demonstrated in depths of 5270 m in the Central Indian Ocean, for the first time ever by any nation.



### 5.6 An effective eco-friendly method of synthesizing promising drug molecules from Antarctic lake bacterium

Researchers at the National Center for Polar and Ocean Research (NCPOR), Goa have devised a highly efficient and eco-friendly method of synthesizing gold nanoparticles from ionic gold using an Antarctic lake bacterium that is tolerant to extreme cold conditions. The method allows scientists to produce high-quality gold nanoparticles without adding synthetic chemical additives such as stabilizing or reducing agents. Such gold nanoparticles hold immense promise as effective therapeutic anti-microbial agents or in composite therapy with anti-cancer, anti-viral, and cholesterol-lowering drugs. The research was published in the 2021 issue of the Journal of Preparative Biochemistry and Biotechnology and was done in collaboration with Goa University.

### 5.7 Technology transfer to industry

Technology licensing agreements with Indian industries through National Research Development Corporation (NRDC) and the details are given below:

- “Remotely Operable Vehicle” to L&T heavy industries and Bharat Electronics Limited. Bangalore
- “Ocean drifter” (Drifting Buoy with INSAT Communication) to M/s. Astra Microwave, Hyderabad and M/s. Azista Industries Pvt. Ltd., Ahmedabad.
- “Wave powered navigational buoy” to M/s. High Tech Elastomers, Ahmadabad M/s. Nireekshan, Chennai, M/s. Sangir Plastic Pvt. Ltd., Valsad.
- “Enterococcus faecalis multiplex PCR detection kit” to SAAI Electro Biogenic India Pvt. Ltd.
- “Lutein production from marine microalgae” to M/s. Vectrogen Biologicals Pvt Ltd., Hyderabad,
- Sea surface temperature sensor, NRDC

## 6 HIGH PERFORMANCE COMPUTING (HPC)

The Ministry of Earth Sciences has augmented its HPC facility to 6.8 Peta Flops (PF) which has been installed at two of its constituent units namely, Indian Institute of Tropical Meteorology (IITM), Pune with 4.0 Peta Flops capacity and National Centre for Medium Range Weather Forecasting (NCMRWF), Noida with 2.8 Peta Flops capacity. The HPC facility 'Pratyush' at IITM and “MIHIR” at NCMRWF were dedicated to the nation by Dr. Harsh Vardhan, Minister for Earth Sciences on 8 January 2019 and 30 January 2019, respectively. The HPC facilities at the Ministry have been substantially augmented by upgrading to the capacity of 1100 Teraflop. With this facility, a paradigm shift in weather and climate modeling activity for operational weather forecast has been achieved.



The HPC system will be a national facility for improving weather and climate forecasts and services under the umbrella of the Ministry of Earth Sciences (MoES), Govt. of India. India's ranking has moved from the 368th position to around the top 30 in the Top500 list of HPC facilities in the world. India is now placed at the 4th position after Japan, UK and USA for dedicated HPC resources for weather/climate community.

This facility is part of Ministry's continuous endeavor to provide world class forecast services to the citizens of India through its various operational and research and development activities. The Ministry of Earth Science has developed several services for societal benefits catering to a variety of sectors of economy by building state-of-the-art systems for multi-hazard risk reduction from cyclones; floods/droughts; heat/cold waves; earthquakes; tsunamis; etc.

## **7. TARGETED BASIC RESEARCH**

Ministry of Earth Sciences also carry out significant research on basic science on different themes. This is aimed to improve and advance fundamental knowledge and it remains as a source of most new scientific ideas and innovation. Basic research is incredibly important because it lays the ground for major discoveries.

### **7.1 Monsoon Mission and Improved Monsoon Predictions**

Accurate prediction of monsoon rainfall is very crucial as it impacts many sectors like agriculture, water resources, power generation, transport and even the Indian economy. The Monsoon Mission was launched in 2012 with an allocation of Rs 400.00 crore to develop the capability of dynamical model prediction systems for short range to seasonal forecasts and to improve the monsoon forecasts. Under the Monsoon Mission, MoES has implemented two state-of-the-art dynamical prediction systems for short range to medium, extended range and seasonal forecasts. All these initiatives have helped to improve the skill of monsoon forecasts over the country. For the first time, IMD used the Monsoon Mission dynamical model to prepare operational seasonal forecast of 2017 monsoon rainfall over India.

After the success of the Monsoon Mission Phase I, the second phase of the mission has been launched in 2017 with the objectives of developing suitable applications and also to improve the prediction of weather and climate extremes.

### **7.2 Release of the national climate change assessment report**

A new open access book on Assessment of Climate Change over the Indian Region has been published in June 2020. This is the first climate change report for the Indian region from the Ministry of Earth Sciences,



and discusses the influence of human-induced global climate change over the Indian subcontinent, the adjoining Indian Ocean, the Himalayas and on the regional monsoon. It also briefly discusses policy relevant information based on robust scientific analysis and assessments of the observed and future projected climate change over the Indian region.

The first-of-its-kind open-access publication in India aims to benefit students, researchers, and policymakers. It documents the regional climate change projections based on the climate models used in the Intergovernmental Panel on Climate Change Fifth Assessment Report and climate change modelling studies using the Indian Institute of Tropical Meteorology Earth System Model and CORDEX South Asia datasets.

### 7.3 Observational Campaigns

Many observational campaigns have been taken up during the past four years as special atmospheric observations help us to understand model deficiencies and to improve prediction models. To address the issue of better measurement and understanding of small-scale processes that drive the variability, seasonality and predictability in the South Asian Monsoon, a large-scale joint India-UK observational campaign was carried out during the period June-July 2016. The campaign involved the deployment of UK's BAe-146-301 atmospheric research aircraft with sophisticated scientific instruments and India's SagarNidhi and SindhuSadhna research ships.



Hon'ble Minister of Science and Technology and Ministry of Earth Sciences, Dr Harsh Vardhan, along with the UK & Indian scientists with the Research Aircraft.

### 7.4 Scientific Deep Drilling

Scientific Deep Drilling in Koyna which started in 2016 is aimed at setting up of borehole observatory (s) at depth for directly measuring the in-situ physical properties of the rocks, pore-fluid pressure, hydrological parameters, temperature and other parameters of an intra-plate, active fault zone in the near field of earthquakes - before, during and after their occurrence, leading to a better understanding of the mechanics of faulting, physics of reservoir triggered earthquakes and preparing a predictive model.

Borehole Geophysics Research Laboratory (BGRL), Karad has undertaken scientific deep drilling and associated investigations in the Koyna seismic zone, Maharashtra. In 2017, the pilot hole of 3 km depth has been drilled with the technical help of International experts.

Detailed geophysical measurements carried out in the borehole provided critical new information regarding the subsurface geology, temperature, physical and mechanical properties and the state of stress to 3 km depth in the seismogenic zone.



### **7.5 Antarctic Expedition**

India is successfully cooperating two research stations, Bharati and Maitri in Antarctic to enhance our understanding glaciology, polar atmosphere, paleo-climate and polar biology. Annual scientific expeditions to Antarctica are being done with scientists drawn from different scientific institutions. The scientific projects included projects on upper atmosphere, astrophysics, geophysics, meteorology, glaciology, geology, biology, environmental sciences, human physiology and medicine. Till date 40 expeditions have been undertaken to the Antarctic.

### **7.6 Himalayan Research Station**

National Centre for Antarctic and Ocean Research (NCAOR), Goa, under the Ministry of Earth Sciences established a high altitude research station in Himalaya called HIMANSH (literally meaning, a slice of ice), situated above 13,500 ft (> 4000 m) at a remote region in Spiti, Himachal Pradesh in 2016. This station provides the much needed support to the researchers and is equipped with many scientific instruments.

### **7.7 Arctic Research**

MOES also continued scientific activities in Arctic at the research Station Himadri, Ny-Ålesund, Svalbard, Norway.. One of the main activities was launching the Indian Arctic mooring (IndARC-II). The Ambient Noise Measurement System with a single hydrophone and a data acquisition system were deployed on IndARC-II. The IndARC-II collected more than 116 parameters and worked continuously in the Arctic waters. Glaciological field studies in Arctic are conducted essentially in two glaciers (VestreBroggerbreen and Feiringbreen) in Svalbard as a part of Indian Arctic Expeditions.

### **7.8 Cloud Aerosol Interaction and Precipitation Enhancement Experiment(CAIPPEEX)**

CAIPPEEX program has two main objectives a) to advance research on the aerosol-cloud and precipitation interactions and b) to conduct cloud seeding experiments by using this background data for planning rain enhancement experiments for protocols of cloud seeding. The CAIPPEEX project has resulted in 820 hours of airborne cloud, aerosol and rain microphysics observations over Indian region and several key results have been published.

### **7.9 High-Altitude Cloud Physics Laboratory (HACPL)**

The HACPL was set up at Mahabaleshwar with advanced measurement facilities for observing the cloud, aerosol, precipitation and radiation parameters to understand aerosol-cloud-precipitation interactions. Using the observations, the indirect effect of atmospheric particulate pollution on cloud properties using HACPL observations and better understanding on role of aerosol physical and chemical properties on cloud activation is established. Long-term continuous measurements of cloud, precipitation and aerosol will provide test-bed for testing/improvement of physical processes relevant to orographic convection, cloud activation and effect of aerosol on precipitation in numerical weather prediction models.

### **7.10. Winter Fog Experiment (WIFEX)**

WIFEX is an observational campaign to understand the complete environment under which the fog develops, its formation and dispersion mechanism being conducted at the Indira Gandhi International Airport (IGIA), New Delhi since last 6 years. Operational forecast for the fog during the winter season are being issued since 2017-18.

### 7.11 Cloud Physics Observatories

The National Centre for Earth Science Studies (NCESS) has established 3 cloud physics observatories in the coastal, mid and high altitude locations in the Western Ghats. The high altitude cloud physics observatory was inaugurated at Rajamallay in Munnar, Kerala on 9th June 2017. The observatory is situated at an altitude of 1820 m above mean sea level and is the highest elevation cloud physics observatory in the Tropical region over the south Asia.

Continuous monitoring of clouds, atmosphere profiles, lightning and rainfall will be improving the knowledge about the convective cloud propagation, mountain weather and lightning. The data collected from this observatory will be used for basic research on heavy rainfall, thunderstorm, monsoon, satellite and aircraft measurements validation and high resolution super computer based weather forecasts validation.

### 7.12 Atmospheric Research Testbed in Tropical Monsoon Core Zone

This open field observatory planned to be spread in 100 acres of land (50 km away from Bhopal) is being established for better understanding on processes governing monsoon convection and land-atmosphere interactions over the core monsoon region using the state-of-the-art observational systems such as RADARS, WIND PROFILERS, UAVs etc. This Atmospheric Research Testbed will be a unique facility in Tropics with first phase of instrumentation.

## 8 CAPACITY BUILDING AND HUMAN RESOURCE DEVELOPMENT

International Training Centre for Operational Oceanography (ITCOcean)

ITCOcean is aimed at promoting the development and optimization of scientific base, technology and information system for operational oceanography at national, regional and global scales. The facility helps in promoting excellence in integrated multidisciplinary oceanography on a global scale. It is also expected that the legacy of the training programme will endure far in to future as it will help building a future ocean system which directly serves the needs of mankind through improved marine monitoring and enhanced stewardship of the seas.

It received the recognition of being a Regional Training Centre of the Ocean Teacher Global Academy project under the International Oceanography Data Exchange for 2020 to 2023. It has conducted several training courses for Indian and international participants towards capacity building in the field of ocean sciences and technology.

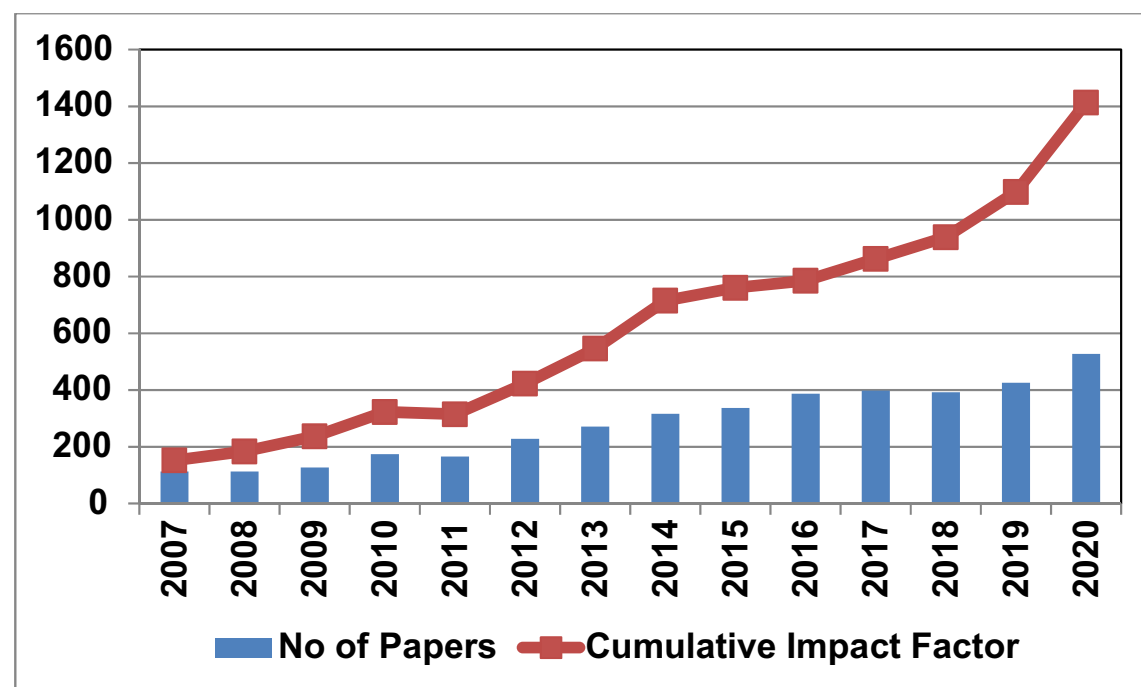
Development of Skilled Manpower in Earth System Science and Climate (DESK)

DESK programme of the MoES implements various schemes for capacity building in the field of earth system science. It implemented annual recruitment and training of research fellows/PhD scholars for MoES and its institutes. It facilitated and conducted summer internships, project training programmes and study tours (4), expert lecture series (3), brainstorming meetings (2), workshops, summits and conferences (3), and webinars (38) for students, scientists and

faculty, officers of the Indian Air Force and Naval meteorological observatories, and meteorology professionals. It also coordinated sharing of resource persons from the Indian Institute of Tropical Meteorology (IITM), Pune, to deliver knowledge and expertise at various national and international platforms.

## 9 SCIENTIFIC PUBLICATIONS

There has been an exponential growth in number of research publications by the scientists of the Ministry during the past few years



Number of research papers and cumulative impact factor year wise

## 10 OUTREACH AND DISSEMINATION OF SERVICES

Launch of mobile applications to enhance the quality of MoES services to the public

IMD's new Mobile App "Mausam" was launched by Dr Harsh Vardhan, Hon'ble Minister of Science and Technology, Health and Family Welfare and Earth Sciences on 27th July 2020. This mobile app is extensively used by the users for knowing location specific forecasts.

In addition, the MoES launched several mobile applications such as Meghdoot, Damini, SAFAR AIR, SARAT, RISEQ, which have helped disseminate real-time information on weather, Ocean, and seismological services.

Dissemination of information through active engagement on social media

The MoES engaged and disseminated helpful information to the public through various social media channels such as Twitter, Facebook, Instagram, and YouTube, which has also increased the direct user base of MoES.

Uninterrupted and efficient data supply to stakeholders

The Data Supply Portal operationalized by IMD in March 2019 has reduced the lag in data delivery from a few months to hours and increased the user base. The stakeholders have a hassle-free web-based procurement of data within an average time of six hours.





***Dr Harsh Vardhan***  
*Hon'ble Minister of Earth Sciences*  
*Government of India*



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